Chapter 4

Assembly and Installation

Once the detector components, discussed in the preceding chapter, have been constructed, then these components must be assembled to create the MINERνA detector.

The basic functional unit of the detector is called a “module”. A module consists of a hexagonal steel frame containing various scintillator packages or absorber material, depending on the type of module being constructed. Overall, the detector will consist of 105 modules.

The assembly of the MINERνA modules is handled in three steps. First, the scintillator is shipped from the extrusion facility at FNAL to Virginia where it is packaged into units that can be easily installed into the detector modules. To do this, the raw extrusions must first be cut to length, reinforced, and glued together into a structurally-robust package. The mirrored wavelength-shifting fibers must be inserted and glued into each extrusion. The final package must be light-tightened and tested. All of this work will take place at two factories located at the College of William and Mary and at Hampton University. This task has been named WBS3 and is being managed by Jeff Nelson of the College of William and Mary.

The second step of assembly involves fabrication of the steel frames which are the main structural unit of each module. These frames are assembled from six steel segments (or “wedges”) which are individually cut from 1.25” thick steel plates. These segments must be welded together to form the frame. This work will be done at Fermilab in Wideband Hall. The task has been named WBS8 and is being managed by Jim Kilmer of Fermilab.

In addition to fabricating the steel frames and absorber material for the detector, WBS8 also includes preparation of a number fixtures required for the detector assembly and installation. This includes the detector stands, strongbacks and a number of related items.

Finally, once the steel frames and scintillator units have been prepared, the modules themselves will actually be assembled. The scintillator will be shipped back to FNAL from Virginia. Scintillator units and nuclear absorber material will be installed into the OD frames. The final units must be scanned with a radioactive source to determine the local performance of the scintillator. This step, known as “mapping”, will also be the main quality control step before installation.

The module assembly task has been been named WBS9 and is managed by Robert Bradford of the University of Rochester (UofR). While module assembly will take place in Wideband Hall at Fermilab, most of the preparatory work is being done at the University of Rochester. In addition to the module assembly and mapping, WBS9 also is responsible for the veto wall, commissioning the tracking prototype, and fabrication of the PMT racks.

Once assembled, the modules will be stored in Wideband Hall until the detector is installed in the

NuMI experimental hall. While it would be ideal for the modules to be installed as they are completed, the feasibility of this, however, is not well understood. The main concern here is that the installation procedure could interfere with the operation of the MINOS near detector. Currently, the collaboration has planned an installation procedure that is minimally invasive for MINOS (during a shutdown), but it still investigating the feasibility of a prompt installation. Because the installation may be latent, it has not been included as part of the Project. Nonetheless, installation related activities are being managed by Jim Kilmer, and this task has been named WBS11.

This chapter, then will be divided into four sections, one four each of the major tasks addressed in this chapter. Section 4.1 will detail construction of the scintillator modules while Section 4.2 will discuss the OD steel frame construction and physical facilities. Final module assembly will be covered in 4.3. Not being technically part of the Project, installation will not be discussed in as much detail as the other three tasks. However, an overview of the detector installation will be presented in Section 4.4. Each section will include a more detailed introduction to the scope of the task, a discussion of required resources, and a breakdown of the main tasks with each WBS structure.

4.1 Scintillator Assembly

WBS3 designs and constructs all scintillator units for the detector. Of these, there are two kinds: The large hexagonal planes of scintillator for the inner detector, and the smaller "tower" of scintillator for the ODHCAL. This section will begin by defining the scope of WBS3, including an overview of both scintillator assemblies, and a discussion of the construction process. Section 4.1.4 will discuss facilities and resources required for the construction, and Section 4.1.5 will discuss interfaces with other WBS tasks and outside vendors. The discussion will end with an overview of the major tasks included in the WBS3 schedule (Section 4.1.6) and a short section on the R&D effort (Section 4.1.7).

4.1.1 Task Objectives and Overview

The specific tasks for which WBS 3 is responsible include:

1. Design the components of the scintillator assemblies.

2. Purchase the construction supplies, component materials and fabricate the components of the scintillator assemblies.

3. Assemble all MINERνA scintillator units. These include assemblies for the MINERνA detector, the tracking prototype, and the full module prototype. The final MINERνA detector will require 196 ID planes and 648 outer detector assemblies. Once production waste, spares, and prototyping efforts are included, we plan to construct 253 ID and 820 OD assemblies.

4. Test the assemblies for dead readout fibers and light leaks.

5. Package and ship the assemblies to the module assembly site at Fermilab.

The following subsections will discuss the specifics of the scintillator assembly design and the assembly procedures.

4.1.2 Design of the scintillator assemblies

WBS3 will design and construct two types of scintillator modules - the ID planes, and the OD towers.

Details of the ID planes are shown in Figure 4.1. The main body of the plane is largely composed of 128 triangular scintillator extrusions, each containing a green WLS fiber. The scintillator extrusions will range in length from 123 to 246 cm and will be glued edge-to-edge using 3M Scotchweld DP190 adhesive to form a large solid hexagonal plane of scintillator. The outer edges of the planes will be treated with a rigid PVC foam, shown as white, yellow, and pink bars in the figure. The yellow bars run parallel to the length of the extrusions and provide structural reinforcement for the plane. At the top of the plane (white bars in the figure), the PVC pieces contain precisely machined grooves which will be used to route the WLS fibers out of the plane for readout purposes. To form a light-tight package, the entire assembly will be wrapped in an outer skin of 0.010" thick Lexan film. A sheet of Lexan, called the "weave", will also be woven through the scintillator plane to provide a convenient gluing surface. A drawing depicting a cut-away side view of a plane is shown in Figure 4.2.

The plane design builds on the success of the MINOS near detector scintillator module assembly [1]. The two assemblies are conceptually very similar - large planar structures composed of extruded scintillator. However, a few modifications are required to meet the needs of MINERνA . Most significantly, the aluminum skins from the MINOS modules were replaced with Lexan; the aluminum skins would have presented too much high-Z material for the MINERνA target region. In addition, the MINERνA triangular strip design uses an axial hole to house the WLS fiber, rather than a groove for better dimensional tolerances.

The readout end of the WLS fibers extends beyond the edge of the planes. In the final assembled module, these fibers must be routed across the face of the OD steel frame. The fiber routing scheme has been carefully planned so that there is appropriate clearance around assembly hardware and other module structure that could damage the fibers. Figure 4.1 shows a typical routing plan. At their extreme ends, these fibers will be arranged into groups of eight and terminated in a DDK connectors. These connectors will provide an optical connection between the WLS fiber and the clear fiber cables that will carry light signals to the readout PMT's. The fiber bundles will be encased in specially designed baggies made of an opaque plastic called "Tufscrim". The DDK connectors will be installed onto the WLS fibers, polished, and mounted onto a piece of metal strapping.

Each assembled detector module will require six OD towers. The OD towers are a scintillator package that will be installed into channels in the steel OD frame and will form the active component of the OD HCAL. Each OD tower consists of eight scintillator extrusions, with a rectangular side profile. The scintillator will be packaged into four individual bundles of two bars, and each bundle will have its own light-tight outer Lexan skin (0.010" thick). Four bundles will be mounted to steel cross pieces that will form an assembly that should mount easily into the channels in the OD frame. The WLS readout fibers will be light-tightened with an opaque baggie, and will terminate with a DDK connector. An engineer's drawing of an OD tower assembly is shown in Figure 4.3.

4.1.3 The ID Plane Assembly Process

The assembly of a MINERνA plane is a multi-step process. The following is a brief overview of the assembly procedure. Many of the figures in this section are photographs we took during assembly of the first MINERνA inner detector plane prototype completed in July, 2006. The this prototype was built at the College of William and Mary by members of the Hampton University and William and Mary groups.

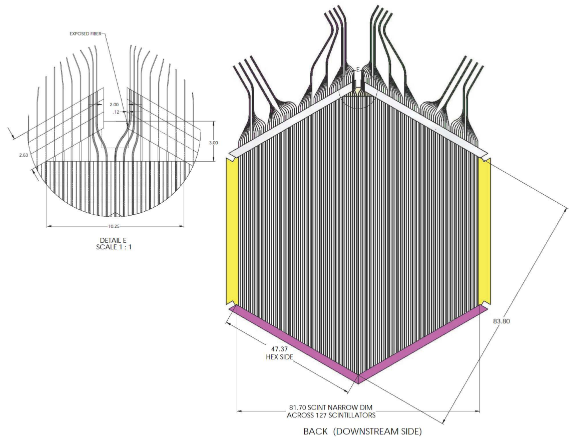

Figure 4.1: Engineer's drawing of an ID scintillator plane. The WLS readout fibers, shown in a typical routing patter, are drawn at the top of the plane. The white, yellow, and pink bands at the edge of the plane represent rigid PVC pieces which will be added to reinforce the plane's structure and aid in the fiber routing. Image courtesy of Robert Flight.

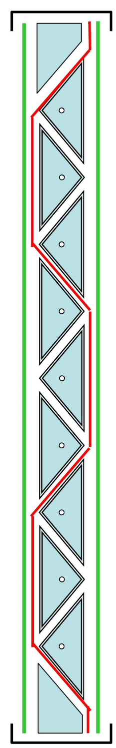

Figure 4.2: Schematic cross-section of an ID scintillator plane assembly. The triangular scintillator strips and PVC edge rails are shown in blue. The Lexan weave (red line), outer skins (green), and end seals (black) are also shown.

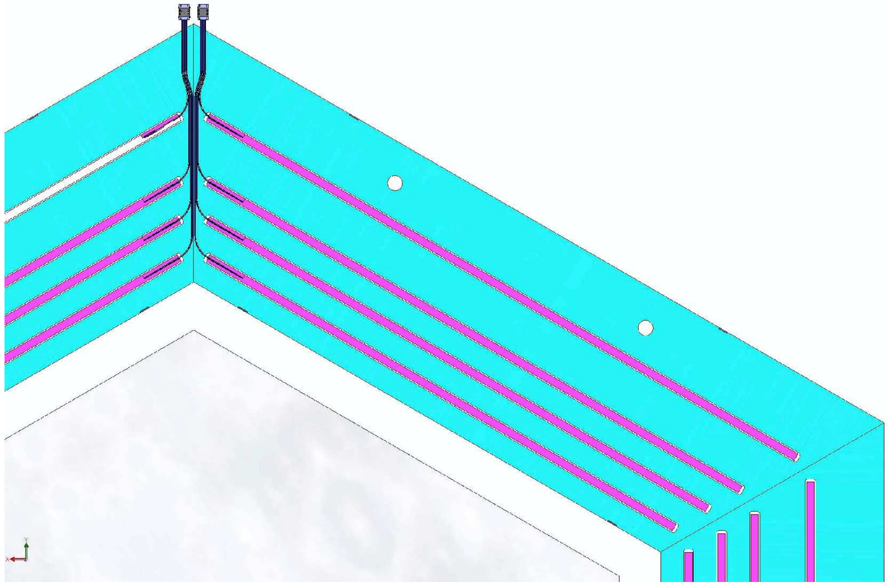

Figure 4.3: Engineer's drawing showing OD towers (in purple) inserted into the OD steel frame (in blue). The WLS fibers and DDK connectors are shown near the peak in the OD frame towards the left of the picture. Figure courtesy of Robert Flight.

Receive and Unpack Scintillator The scintillator extrusions will be manufactured at the Fermilab-NIU extrusion facility. The extrusions will be crated and shipped to the scintillator assembly factories in Virginia. As neither the William and Mary nor the Hampton University physics builds have sufficient room to store a truckload of scintillator, a central warehouse will be used for receiving and storage. This warehouse will be climate-controlled. As need dictates, scintillator will be unpacked and transferred to the assembly factories.

Cut Scintillator to Length As manufactured, the extrusions will all be roughly 4 meters in length. Construction of the hexagonal plane, on the other hand, will require scintillator bars of roughly 123 to 256 cm in length. The first step, then, in the manufacturing process will be to cut the extrusions to the proper length.

A cutting table has been developed to aid in the cutting. The table incorporates a system of rails with stops used to properly position a cutting fence. The scintillator will be cut by a saw equipped with a carbide-tipped blade used for cutting plastics. As plastics are best cut with a slow blade speed, the saw blade will be slowed down using a Variac controller. One quarter of the scintillator required for each plane will be cut in a single pass. A photograph of the prototype cutting table is shown in Figure 4.4.

During the cutting process, the waste scintillator removed by the saw blade, called flashing, tends to melt, adhere to the extrusions, and clog the fiber holes. After cutting, the flashing will have to be removed from the end of the extrusions. The holes used to hold the WLS fibers will also be inspected and cleared using dental tools.

Assemble Lower Half of Plane The lower Lexan skin will then laid out on a large work surface. A layer of glue will be applied to the skin, and then the lower scintillator bars (those lying below the

Figure 4.4: A photo of the ID scintillator cutting table.

Lexan weave) will positioned on top of the skin. More glue will be applied to the scintillator, and the Lexan weave peace which runs through the plane will be positioned on top of the scintillator. At this point, the PVC edge pieces will also be positioned on top of the lower skin. Figure 4.5 shows a photograph of the lower half plane assembly.

A vacuum seal will be applied, and the assembly will be left to cure overnight.

Assemble Upper Half of Plane The next day, more epoxy will be applied to the top of the weave, and the upper scintillator bars and top skin will be added. The plane will then be left to vacuum cure for another day. Figure 4.6 shows an assembled plane (both upper and lower extrusions having been positioned and glued) while it vacuum cures.

Insert and Glue Fibers After the structure has been assembled, the WLS fibers will be inserted and glued into place. A special gluing machine will be used to inject optical epoxy into the fiber hole in each extrusion.

Install Fiber Baggies The readout end of the WLS fibers must follow an appropriate path across the outer OD steel frame in order to avoid damaging the fibers. A sheet of opaque "Tufscrim" will be used as a routing substrate; the fibers will be fixed into position on the Tufscrim with carpet tape. An upper Tufscrim cover will be added, and the two halves will be heat sealed and taped together to form a light-tight baggie for the fibers.

Install and Polish DDK Connectors The readout ends of the WLS fibers will be mounted in a "ferrule" which will allow the fibers to plug into a DDK connector. The fibers will be glued into the

Figure 4.5: Photo showing main components of the lower half plane. The PVC edge pieces are visible towards the top of the photograph. The scintillator extrusions are shown lying under the Lexan weave.

Figure 4.6: The first prototype MINERνA scintillator plane while it vacuum cures.

ferrule, and the entire assembly will be polished using a fly-cutter. 16 connectors will be installed for each plane. The connectors themselves will be mounted to a piece of 1/8" thick aluminum stock. During module assembly, this aluminum stock will be installed on connector mounts on the outer edge of each module's steel frame.

QA and Light-Leak Testing The final assembly step will be a QA procedure. Planes will be inspected for light leaks, broken fibers, and other troubles.

Ship to Fermilab Finished scintillator planes will be placed in plywood shipping crates and stored at the central warehouse facility. Once a shipment is complete, the full crates will be sent to the module assembly factories at Fermilab by flat-bed truck.

There will be three assembly periods. First, we will assemble two planes plus a spare and 6 towers plus a spare for the full module prototype in 2006. A year later, we will assemble 40 planes plus spares and 120 towers for the tracking prototype. Finally, we will construct the production assemblies for the final detector in 2008 and 2009.

OD Tower Assembly

The outer detector assembly is significantly simpler will be overall much less labor intensive. The process begins by cutting the scintillator extrusions to one of four prescribed lengths. Once cut, grooves must be machined in the end of each extrusion to permit routing of the WLS fiber out of the scintillator. Two extrusions of the same length will be glued together, and fitted with a Lexan skin to form a "bundle". WLS fibers will be inserted into each extrusion in the bundle and glued into place with optical epoxy. Steel straps will be fixed to four bundles to form the basic structure of the OD tower.

The readout end of each fiber will be covered with an opaque plastic baggie, and one DDK connector ferrule will be installed and polished on each OD tower.

Using the MINOS manpower requirements as guidance, the expected production rate is ten OD towers per 35 hours of labor.

4.1.4 Facilities and Resources

The construction of the MINERνA scintillator assemblies will be undertaken at both Hampton University and the College of William and Mary. Both programs have extensive experience in detector production. Since the two institutions are located less than 25 miles from each other (and less than 15 miles from JLab), they provide a natural team for undertaking a joint detector production program. This team will benefit from a collaborative prototyping program, and the joint set-up costs are minimal for this project. Bulk purchasing responsibilities will be shared by the two institutions, according to the particular strengths and experience of each.

Each university will provide suitable laboratory space to run an assembly factory. The space must be large enough to safely accommodate the construction of the hexagonal ID planes, which are roughly 256 cm in their largest dimension. The fabrication sites must also have appropriate clearance to permit the planes to pass in and out of the building.

Aside form the basic lab space, both assembly sites must be appropriately outfitted for the construction tasks. The required resources will include:

1. Scintillator cutting station.

2. Folding station necessary to produce the Lexan weave pieces.
3. Work surfaces to accommodate both ID plane and OD tower assembly. The surfaces must suitably flat and air-tight to facilitate vacuum curing of the epoxy.
4. Vacuum pumps and bags required for vacuum curing.
5. Adhesive mixing and dispensing equipment (required for structural epoxy).
6. Fly cutter (used to polish DDK connectors)
7. Gluing machine (used to dispense optical epoxy for gluing WLS fibers into scintillator).
8. Facilities and rigging to permit overhead lifting. This will be required to load the scintillator assemblies into shipping crates.
9. Appropriate tooling and safety equipment.

The William and Mary site will be partially outfitted with a gluing machine and fly cutter obtained from the MINOS scintillator assembly factories.

Both sites will be staffed with a mix of full-time technicians and student labor. Graduate students and technicians will be used to supervise teams of undergraduate labor. Each assembly site will require the equivalent of five full-time laborers. Most custom machining will be done at the William and Mary machine shop.

A shared off-campus facility will be used for storage, shipping and receiving. This facility must be climate controlled to prevent damage to the scintillator during storage, and must have necessary materials handling equipment to permit movement of the large crates used to ship the ID planes. This facility will be used to receive shipments of scintillator from Fermilab. The shipping facility will be used to store the raw extrusions before they are dispatched to the assembly factories. As scintillator assemblies are completed, they will be packaged for shipping and loaded into crates at the factories. Loaded crates will then be moved to the shipping facility, where they will be stored until a full truckload is assembled. Then, the completed assemblies will be shipped to Fermilab.

4.1.5 Interfaces with other WBS Tasks

WBS3 will receive supplies and materials from three other WBS tasks: WBS1, WBS2, and WBS4. WBS1 will provide the scintillator extrusions. These will be produced at the NIU-Fermilab extrusion facility, and then shipped to Virginia. WBS2 will provide the WLS fibers. This effort is being lead by a group from the University of Rochester working at Fermilab. WBS2 will acquire the fiber from the vendor, verify the fiber quality, mirror one end, and then ship the fiber to Virginia. The fibers will be supplied to WBS3 pre-cut to their appropriate lengths. WBS4 will supply the optical connectors and fly cutting bits required to polish them. WBS4 will perform the majority of connector-related R&D, spec the connectors to the vendor (DDK), and handle the procurement.

The final WBS interface is with WBS9, module assembly and mapping. The completed scintillator assemblies will be shipped to the module assembly factories at Fermilab, where WBS9 will use the ID planes and OD towers to build the final detector modules.

WBS3 will also maintain a number of minor interfaces with private vendors who supply material required for the scintillator assemblies. Epoxy, Lexan, opaque plastic, and PVC foam will all be supplied by private vendors.

4.1.6 Major Tasks

This section will give an overview of the tasks that we have scheduled for the next several years. The subsections will each refer to a specific task or group of tasks in the MINERνA Project file.

- WBS 3.1.1 - WBS3.1.3: These tasks cover initial R&D and design work for the scintillator assemblies during 2005-2006. The scintillator units will be designed and prototype assemblies will be constructed. Issues relating to the integration of the planes and towers into the MINERνA detector modules will be resolved. Connector polishing techniques will be tested and practiced.
- WBS 3.1.4-5: These tasks cover outfitting of the scintillator assembly factories at both Hampton University and the College of William and Mary. Workstations will be constructed, and tooling will be purchased during the summer and fall of 2006.
- WBS 3.1.6-9 - Full Module Prototype Scintillator Assemblies: In the fall of 2006, a prototype detector module will be build at Fermilab. These tasks cover production of three ID planes and seven OD towers for the prototype module.
- WBS 3.2 - Tracking Prototype: The tracking prototype will consist of 20 detector modules that will be built in the fall of 2007. Tasks under WBS 3.2 cover production of the ID planes and OD towers for the tracking prototype. Tasks cover procurement of the materials for the factories, construction of the assemblies, and shipping of the complete assemblies back to Fermilab.
- WBS 3.3.1-4 Detector components and materials: After the tracking prototype is completed, the assembly factories will prepare for the construction of the final (production) detector. WBS3.3.1-4 cover procurement of materials for the production detector. This work will take place in late 2007 and early 2008.
- WBS 3.3.5-6 Detector assembly: The scintillator assembly factories will open for their third and final time in mid 2008. These tasks are the construction of the ID planes and OD towers for the production detector.
- WBS 3.3.8 - Storage and shipping: The last step in the process will be to package the final assemblies in shipping crates, store them, and then ship them to Fermilab. This work will be completed in mid to late 2008.

4.1.7 R&D and value engineering

A significant amount of R&D has already been completed. In the summer of 2005, a W&M undergraduate researched techniques for injecting optical epoxy into the fiber holes of the scintillator extrusions. Optical epoxy improves the optical contact between the WLS fiber and the scintillator, improving the light collection efficiency of the system. Two different glues were tested, 815C and Eljen optical epoxy. 815C was chosen because it produced the highest light yield. Glue mixing and injection techniques were also researched. In the production factory, glue will be injected into the fiber hole with an air driven glue machine. Final techniques were used to glue WLS fiber into the vertical slice test, a small array of scintillator used by WBS2 to test detector optics and tracking.

In 2006, significant amounts of time were spent interfacing with WBS8 and 9 to resolve fiber routing issues. In the final detector modules, the WLS fibers will be routed across the OD steel frame. The fiber path across the steel frame is where the WLS fibers will be least protected and most susceptible to damage. Hence, the path must protect the fibers as much as possible, while being consistent with the overall module design.

With assembly of the prototype plane in the summer of 2006, there was significant development of the cutting table and other factory workstations.

As planes and towers are developed for the full module prototype, factory outfitting and production techniques will be refined in late 2006 and early 2007.

4.2 OD Steel Frame Construction and Physical Facilities

WBS 8 is responsible for fabrication of the detector module OD steel frames and steel fixtures to be used in Wideband Hall during the detector assembly. In addition, WBS8 procures all nuclear absorber material for the detector calorimeters and assembles the upstream nuclear targets.

This work will be performed largely by Fermilab technicians and a variety of public vendors. Many of the WBS8 tasks strongly resemble work recently for the NuMI /Minos project. WBS8 will attempt to profit from this experience by using the same staff and technicians to complete work on MINERνA .

This section will present an overview of WBS8. The scope and task objectives for WBS8 will be presented in Section 4.2.1. Required facilities (Section 4.2.2), interfaces with other WBS tasks (Section 4.2.3), and an overview of the WBS8 schedule (Section 4.2.4) will follow.

4.2.1 Task Objectives and Overview

WBS8 is explicitly responsible for the following tasks:

1. Procure steel for OD detector frames: Each frame will be constructed from six "wedges" (See Figure 4.7.) which will be flame cut from 1.25" thick steel plates. These frames will be the principle structural unit in each detector module, and will also serve as absorber material for the OD hadronic calorimeter. Each wedge will have four channels cut along its length; these channels will house the scintillator bars that are the active component of the OD HCAL.

   This task has two major considerations. First, the steel plate from which the wedges will be fabricated, and second, the actual cutting of these pieces into the wedges.

   The steel plate is specified in [2]. The steel used in MINERνA will be identical to that used by MINOS. While a magnetic coil is not in the baseline design for MINERνA , this steel is suitable for use as a magnet and preserves the possibility of a magnetic field as a future upgrade. The most important parameter of the steel plates is its flatness. In the specification, the upper limit is required to be 1/2 of the ASTM standard limit for flatness in plates; for MINERνA, this translates to a flatness of less than 3/16". For the MINOS project a steel mill was able to routinely provide material that was within the specification. Less than 1% of the over 4000 plates in Minos were out of spec.

   Cutting the steel is specified in [3]. In this specification are the tolerances for the part dimensions, flatness of the finished pieces, and fabrication methods. The vendor will evaluate the flatness of the finished pieces on a case-by-case basis. Parts will be flattened as required by the specification. Contingency for the steel pieces is sufficient to cover any additional costs associated with flattening.

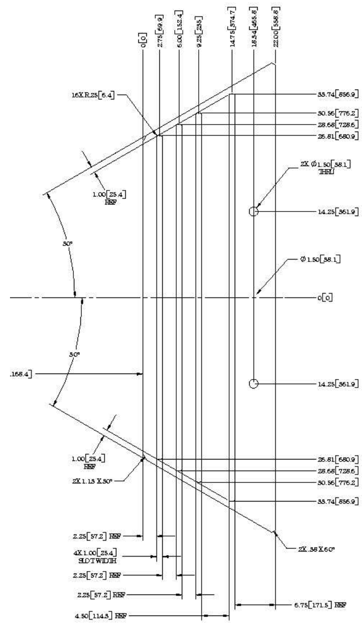

Figure 4.7: The OD frames are each assembled from six “wedges” shown here in an engineer’s drawing.

2. OD Frame Assembly: The steel wedges previously described must be welded to form the OD frames. This work will be done by Fermilab technicians and welders just before each detector module is assembled. Six wedges will be clamped into place on a strongback. The strongback will be held vertically, and the wedges will be welded together to form the frame.

3. Detector Stands, Bookends, and Axial Bolts: WBS8 supplies all fixtures required to mount the detector. The detector stand will hold MINERνA modules much like a hanging file system in a file drawer. The first module will be anchored to a bookend structural element at the end of the stand. This bookend will keep the modules stable and plumb. Axial bolts will then be used to anchor each succeeding module to the one previously installed. Six axial bolts will be used for each module. Figure 4.8 shows a drawing of an axial bolt and Figure 4.9 shows a drawing of the detector stand. MINERνA will require two detector stands in the NuMI experimental hall (one holds the detector in the beam, while a second is used to stage modules during installation) and three smaller detector stands to be used in Wideband Hall during module assembly. Each detector stand must be outfitted with a bookend.

   Fermilab uses the American Institute of Steel Construction, Manual of Steel Construction as the safety code for all structural steel fabrications such as the stand and lifting fixtures.

4. Strongbacks: A strongback is a steel framework that supports modules during assembly and protects them during lifting operations. WBS8 will procure three strongbacks for use in Wideband Hall during the production frame welding and module assembly periods.

   For WBS8’s specific interests, the strongbacks will serve as a welding jig during frame construction. The six wedges of steel will be placed on the strongback in the correct position and clamped

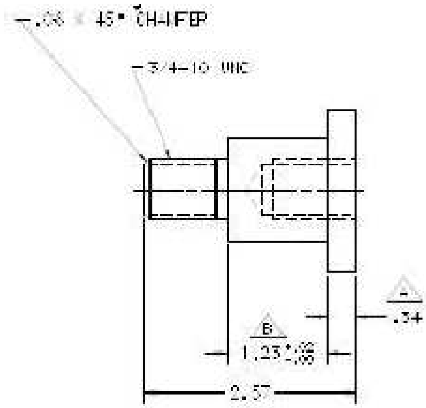

Figure 4.8: Engineer's drawing of an axial bolt.

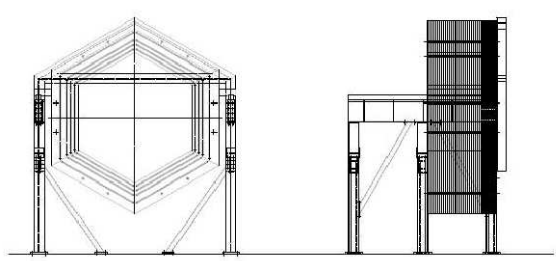

Figure 4.9: Engineer's drawing showing front and side view of the MINERνA detector stand.

down by a series of holding bars. These bars will keep the frame from distorting as it is welded together. After tacking the wedges together the strongback will be moved to a vertical holding fixture that allows the frames to be welded on both sides.

As a lifting fixture the strongback allows the frames to be built on the floor horizontally and then raised to vertical for hanging on the support rails. The pick point on the strongback is chosen so that the frame never hangs exactly vertical but always has a slight tilt so the load is stable with the load's center of gravity on top of the strongback.

Finally the strongback is used as the transport fixture for moving the frames from the Wideband hall to the Minos cavern. Frames are kept on the strongback as they are loaded on the truck for hauling to the surface building.

For lifting fixtures, the "ANSI/ASME B30.20, Below-the-Hook Lifting Devices" safety standard will be used.

5. Procure nuclear absorber material: WBS8 is to procure lead for the MINERνA OD and DS ECAL and steel for the DS HCAL.

   The OD ECAL is constructed by mounting a lead collar the outer edges of the scintillator planes which make up the tracking volume of the detector. The collars are constructed from six wedge shaped pieces of lead. In the DS ECAL modules, the entire face of the scintillator planes are to be covered with a hexagonal sheet of lead. In the DS HCAL modules, hexagonal sheets of steel replace one of the scintillator planes.

6. Construct US Nuclear Targets: WBS8 is to procure lead, steel, and graphite for the US nuclear targets. While these materials will be supplied by outside vendors, the nuclear targets will be assembled by FNAL technicians.

7. PMT Access Platform: The phototube access platform is needed allow a technician to service the the phototubes and the front end electronics, which are mounted above the detector. This will be a rolling platform mounted on rails above MINERνA. The platform will not have drive motors a technician should easily be able to push it along the beam axis of the detector to reach any phototube box or fiber cable.

4.2.2 Facilities and Resources

The work required by WBS8 will be accomplished by a mix of FNAL resources and an array of outside vendors. All of the WBS8 design work will be accomplished by FNAL engineers and drafters, with some support from Robert Flight of the University of Rochester. The resulting drawings will then be taken to local vendors for fabrication work. Fermilab technicians and welders will also be used during times of OD frame construction. The Fermilab technicians that will be working on the Minerva project are the same crew that assembled all of the detector planes for the Minos Near Detector. They have experience with the procedures and the material handling facilities available in the buildings. They also have training for using the cranes, forklifts and working with lead.

The major construction of the Minerva experiment will occur in the old Wideband Experimental Hall. This is where the OD frames and nuclear targets will be assembled. This building has two 15 ton cranes available for assembling the frames and moving materials in the building. Wideband lab has sufficient electrical utilities for welding and power tools required and will be equipped with an electric forklift for material handling in the building. The north end of the building will be used for storing, preparing and handling the steel parts of the detector and the south end will be used for storing and handling the active scintillator elements. The far south end of the building will have a cage securing access to the frame mapper and its radiation source.

4.2.3 Interfaces

WBS8 maintains a large number of interfaces, both with other WBS task groups and also with public vendors.

WBS8 relies on public vendors largely for supply and fabrication tasks. Because of the MINOS project, WBS8 has past experience with many of the vendors who will be handling MINERνA tasks. The most important, and involved, vendor interfaces will be with the suppliers of the OD wedges. MINERνA will be assigned a priority in a steel mill's work schedule, so procurement of the steel will have a large lead time. Since the critical specification of the steel is the flatness of the wedges it will be most important to monitor the quality of the steel parts with a Quality Assurance plan. Besides regular measurements of the parts as they are received it will be necessary to make some visits to the factory during production startup and periodically thereafter if the parts go out of tolerance.

The second interface is with WBS9. Once finished, OD frames will be delivered to WBS9 who will use the frames to construct detector modules. As frame assembly and module assembly will proceed in tandem, frames will be delivered to WBS9 individually as they are assembled. WBS9 will receive each frame sitting on a strongback in Wideband Hall. WBS 8 will also supply WBS 9 with all of the strongbacks and detector stands required to outfit Wideband Hall for module assembly.

The third interface is with the Installation and Infrastructure task WBS11. WBS8 supplies WBS11 with a number of fixtures required for the detector installation. These fixtures include the detector stand, axial bolts, bookends, PMT access platform, strongbacks, and the MINERνA nuclear targets. There is substantial overlap between WBS8 and WBS11; many of the installation tasks will be handled by the same FNAL crew and technicians that assemble the OD frames.

4.2.4 Major Tasks

The major tasks required to complete WBS8 include:

- WBS 8.1.1 and 8.1.2 - Prototype Design Work: These tasks include all of the design and engineering work for items such as the detector stands, axial bolts, strongbacks, and the PMT access platform. While the bulk of the work is to be done by FNAL engineers and drafters (WBS 8.1.2), Robert Flight at the University of Rochester, will give assistance with some tasks (WBS 8.1.1).

- WBS 8.1.3 - Procure Prototype Materials: This task completes procurement of all materials needed for early prototyping efforts, including the full module prototype. For the full module prototype, WBS8 will deliver a prototype detector stand and bookend, one OD frame, a strongback, and a set of axial bolts.

- WBS8.1.4 - Assemble Prototype Stand in Wideband Hall: This task covers installation of the prototype detector stand in Wideband Hall, which must be completed before the full module prototype is built.

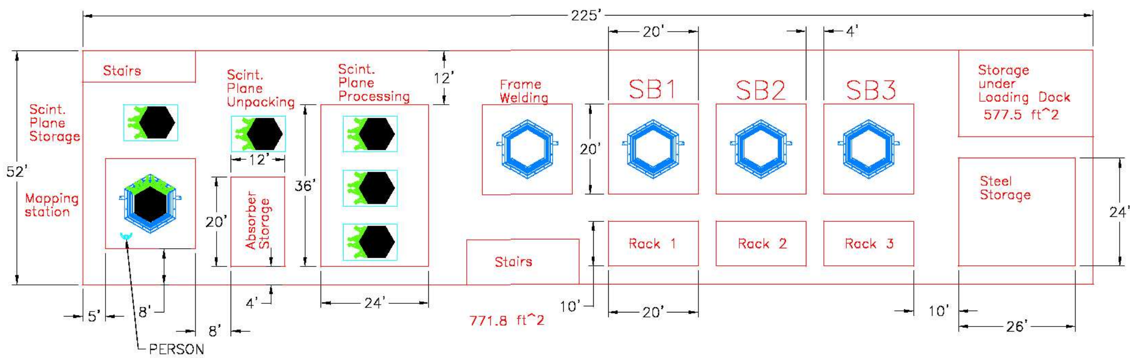

Figure 4.10: This engineering drawing shows an initial concept of the Wideband Hall layout. Most frame assembly and module assembly activities take place on the strongbacks, labeled “SB1”, “SB2”, and “SB3” in the drawing. Areas for scintillator preparation and module mapping to the left in the drawing. Drawing courtesy of R. Flight.

- WBS 8.1.5 - Outer Detector Frame Prototyping: This task covers assembly, welding, and testing of the OD frame for the full module prototype.

- WBS 8.2.1 - Procure Tracking Prototype Materials: These are all the procurement tasks for the tracking prototype.

- WBS 8.2.3 - Tracking Prototype OD Fabrication: This task is construction of all the OD frames for the tracking prototype.

- WBS 8.3.2 - Procure Production Materials: These are the final procurement tasks required for the production detector assembly. Final OD steel wedges, strongbacks, detector stands and axial bolts will be purchased.

- WBS 8.3.3 - Production OD Fabrication: This task covers construction of the OD frames for the production detector assembly period.

In general, tasks falling under WBS 8.1 will occur during 2006, tasks under WBS 8.2 will happen during 2007, and tasks under WBS 8.3 will occur in 2008-2009.

4.3 Module Assembly and Veto Wall

The main tasks of module assembly are to construct and map all MINERνA detector modules, and build the veto wall. These are the last construction steps before the detector is ready for installation. In addition, we are also responsible for a number of related tasks, such as construction of the PMT racks and the module mapper.

While the final module assembly and mapping for the detector will take place at Fermilab during a period of approximately six months in 2009, the preparations for module assembly require a multi-year effort that is being lead by the University of Rochester, with contributions from Fermilab and collaborators from Peru. The preparatory efforts entail an extensive program of building prototypes, development of assembly protocols, designing custom hardware, procurement, and fabrication. Because module assembly involves the integration of components built by other WBS task groups, our preparations also must emphasize communication with the other L2 managers responsible for these systems.

This section will begin by presenting an overview of WBS9. This will include an overview of the module assembly and mapping process and some discussion of the less obvious aspects of WBS9, such as the fabrication of PMT racks. We will then move onto a discussion of how WBS9 plans to meet these objectives. This will include an overview of resources required both from Fermilab and the university groups, a discussion of the interfaces with other WBS tasks, and an overview of the specific activities that we have scheduled for the next few years.

4.3.1 Task Objectives and Overview

The specific tasks that WBS9 is responsible for include:

1. Assemble all MINERνA detector modules and map the local response of the scintillator. These include modules for the final detector, the tracking prototype, and the full module prototype.

2. Design and construct the module mapper.

3. Install and commission the tracking prototype.
4. Fabricate mounting racks for the PMT's and develop tools required for PMT maintenance.
5. Develop routing scheme for clear fiber cable routing.
6. Construct the veto wall.

The following subsections will discuss the specifics of each task.

Module Assembly and Mapping Procedure

Assembling a MINERνA module is a multi-step process. The following is a brief overview of the module assembly procedure as we currently envision it. Many of the figures in this section are based on photographs we took during mock assembly exercises that were conducted at the University of Rochester using prototype modules constructed from wood. More details about the module assembly prodedure are contained in [4].

Receive and prepare materials WBS9 receives scintillator modules from WBS3. Once these modules arrive at Fermilab from Virginia, we will receive the materials and store them in Wideband Hall.

Once the assembly factory opens, the first step will be to unpack and prepare the scintillator. ID planes and OD towers will be inspected for any obvious shipping damage and broken WLS fibers. If the schedule calls for active target modules or DSECAL modules to be assembled, then sheets or collars of lead absorber material will be applied to the US face of the scintillator planes. Layout and identification marking will be applied to the modules.

Steel frames will be provided by WBS8. These frames will be inspected and deburred to ensure that rough edges do not damage scintillator or fibers. Markings identifying the type of module to be built will be applied. A traveler providing more specific instructions will also be affixed. After work on the OD frame has finished, the assembly area will be cleaned.

Figure 4.11 shows a model OD frame mounted on a strongback.

OD scintillator installation The scintillator towers will be installed by hand into the slots cut into the OD steel frame. We will use silicone caulk to secure the scintillator towers into the OD frames. A bead of caulk will be applied to the sidewall of the channels in the OD frames. As the scintillator bars are installed into these channels, the caulk will fill the gap between the scintillator and the steel frame. Installing the caulk before the scintillator minimizes any mess. Figure 4.12 shows a picture of an installed OD scintillator assembly.

Load-bearing spacer and connector mounting installation The load-bearing spacer will consist of four blocks of material which bolt to the inside surface of the bottom two sectors of the steel frame. This material will bear the weight of the scintillator planes or absorber material that will later be installed into the inner detector. These blocks will be held into position by studs which will have been welded to the OD frame by WBS8.

The connector mounting consists of aluminum angle stock that will mount to the outside surface of three OD sectors. The clear fiber cable connectors will later mount to this angle stock. Like the load bearing spacer, these pieces will be held by studs which will have been previously welded to the OD frame.

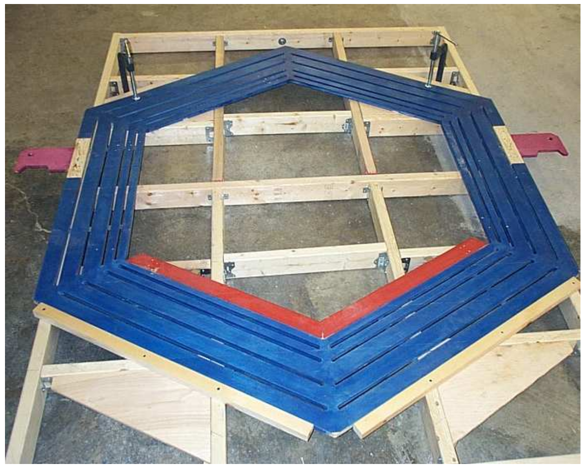

Figure 4.11: At this point, the steel frame has been welded and is mounted on the steel frame. It is inspected, cleaned, marked, and prepared for assembly.

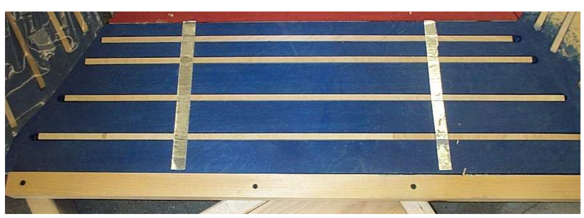

Figure 4.12: The OD scintillator fits in a series of channels in the OD steel frame. The metal bars, which are perpendicular to the scintillator bars, will be a structural element of the assembly. On an actual module, the scintillator assembly will be held into place with silicone caulk.

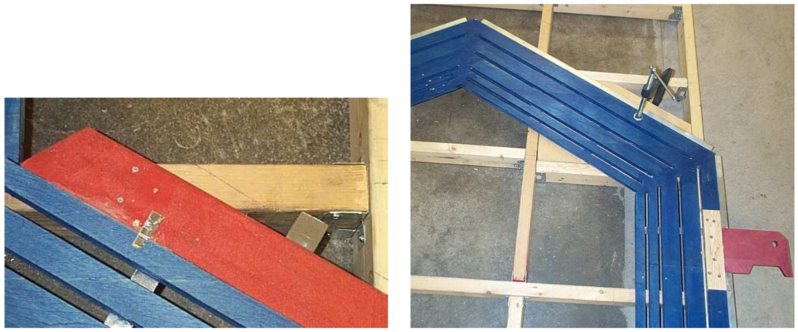

Figure 4.13: *Left:* Close-up photograph shows the load-bearing spacer (in red) mounted on the OD frame (in blue). *Right:* Angle stock for ID scintillator clear fiber connector mounting attaches to the outer face of the OD steel frame. Note pieces located above and below the module mounting hook.

Pictures of the load-bearing spacer and connector mounting on our model are shown in Figure 4.13.

US plane or absorber material installation The first ID material will then be installed. For most modules, the first scintillator plane will be installed at this point. The scintillator plane will be moved into position with the aid of the Wideband Hall overhead crane and a vacuum lifting fixture. This plane will be installed in a "u" or "v" orientation, depending on the assembly schedule. The WLS fibers from this first scintillator plane will be routed across two sectors of the OD steel frame and the clear fiber connectors will be attached to the mounting stock.

Downstream HCAL modules do not have an US scintillator plane. In these modules, the US scintillator planes is replaced with a large steel plate. These plates will be installed during frame assembly by WBS8.

DS plane installation All module types incorporate a DS scintillator plane. In most modules, this plane will always be installed in an "x" orientation. However, the DS plane in the DSHCAL modules may have an "x", "u" or "v" orientation. Once the plane has been moved into position, the fiber packages will again be routed across the OD steel frame and the connectors will be installed.

H-clip installation The scintillator planes will be fixed into position by a hardware piece we have called an "h-clip". A picture of an h-clip is shown in Figure 4.14.

Module mapping At this point, the module will be mapped. Mapping will be discussed in greater detail in Section 4.3.1. If the mapping procedure reveals that a module will perform unacceptably, then we will troubleshoot and remap the module at this point.

Package module for storage The module will then be packaged to minimize the risk of damage during storage and installation. Lengths of 2"X4" lumber will be fixed to the OD frame through the axial bolt holes. These wooden "bumpers" will minimize the risk of crushing fibers.


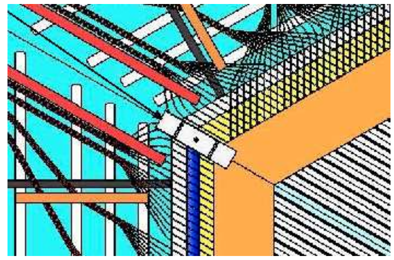

Figure 4.14: *Left:* Close photograph shows prototype H-clip used during early study of detector assembly. The clip spans the air gap between the ID scintillator planes (green) and the OD steel (blue and tan). Note that the clip consists of two metal straps held into position by a bolt. *Right:* Preliminary engineering drawing showing an h-clip being used to fasten a scintillator plane assembly (to the lower right of the picture) to an OD frame (upper left of the picture in blue). Image source: [7].

Store module The module is then moved to the storage rack in Wideband Hall, where it will await installation into the NuMI Experimental Hall. A picture of a completed module is shown in Figure 4.15.

After a factory startup period, we are planning to assemble modules at a rate of one per day. There will be three assembly periods. First, we will assemble one module for the full module prototype that will be built in Fall of 2006. A year later, we will assemble twenty modules for the tracking prototype. Finally, we will construct the production detector modules in early 2009.

Design and Construct Module Mapper

Every detector module will be mapped after it has been assembled. The purpose of mapping is to study the local response of the scintillator. The mapper will scan the scintillator of all detector modules at predetermined points with a radioactive source. The response of the scintillator as a function of position will then be recorded by computer. Mapping allows us to identify any irregularities in the scintillator that will affect the detector performance so that we can account for this while analyzing data. Mapping is also one of our main quality assurance measures for each assembled module.

In consideration of radiation safety, we have decided that the mapper will remain within a fenced area at one end of Wideband Hall at all times. Modules will be transported to the mapping area by use of the Wideband Hall overhead crane. The module and strongback will be positioned on the floor in the mapping area, and then the mapper will be moved into position above the module.

While we have not yet completed our mapper design, an initial engineer's drawing is shown in Figure 4.16. As shown in the Figure, the mapper will consist of a large, heavy steel frame and a scanning carriage that incorporates two scanning heads. The frame must be large enough to span an assembled module and rigid enough to withstand the stress of repeated lifting. Each scanning head will incorporate a 5-10 milli-Curie Cs-137 radioactive source shielded in a lead cone. The scanning heads will travel on rails and the motion will be provided by lead screws driven by electric motors. The motors will be controlled by a nearby computer.

Figure 4.15: The completed module has been moved to a storage rack. The DS face of the module here is shown so that the WLS fibers can be viewed.

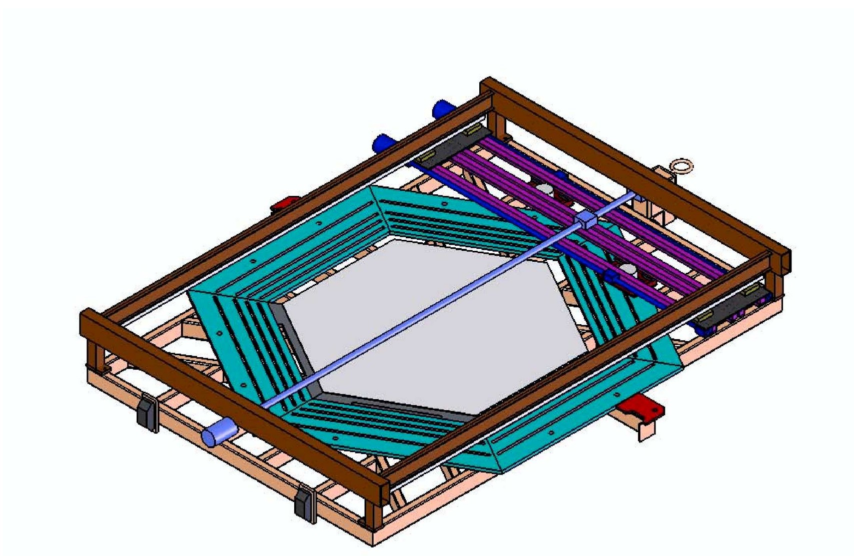

Figure 4.16: The module mapper will be moved into position over the module and strongback. Image source: [6].

As a module is mapped, the scintillator response will ready out using M64 PMT's and a prototype electronics system controlled by a computer.

The design goal of the mapper is to safety scan one module within a period of 10-12 hours.

Assemble and Commission the Tracking Prototype

WBS9 has been asked to assemble and commission the tracking prototype. As the modules are assembled, our technicians will "install" the detector on a detector stand in Wideband Hall. This installation exercise, unlike the final detector installation, is part of the Project and has been assigned to WBS9. As modules are secured on the stand, PMT's and readout cabling will also be installed.

Commissioning will be a busy time, and will involve input from more than just WBS9. As the detector is turned on, there will be representatives from all levels of the collaboration interested in verifying the performance of specific systems. We will have expertise in the detector modules, but we will largely be reliant on experts from other tasks to handle problems with other systems, such as electronics and software. During this initial period, we will coordinate activities in the Wideband Hall and provide support to the various groups. We will ensure that groups have the tooling and resources they need to perform their work safely.

As the detector stabilizes and most of the immediate problems are solved, one of the major commissioning activities will be the collection of cosmic ray data over a period of 4-6 weeks. WBS9 will ensure that the counting house is staffed with a shift crew. We will also verify that the shift crew has been properly trained, that necessary documentation has been provided, and ensure that the daily plan for shift workers is properly implemented.

PMT Racks and Clear Fiber Cable Routing

WBS9 will address certain issues related to the installation and handling of the PMT's and clear fiber cables. This responsibility was assigned to WBS9 because our lab at the University of Rochester has the capacity to fabricate wooden models of detector components. We fabricated a full-sized model PMT rack based on early engineering designs and used this to study routing of the clear fiber cables and PMT box handling and maintenance issues.

The racks will be designed by a mechanical engineer at the University of Rochester. The final design will be based heavily on our experience with the wooden prototype rack. Racks will be fabricated in Rochester by a off-campus machine shop. Because the PMT's are to be mounted on top of the detector, they must accessed from an overhead platform that will be provided by WBS8. WBS9 will also design and provide a lifting jig that can be used during PMT maintenance. Lifting a PMT must be done carefully in order to minimize the possibility of damaging the fiber optic cables used to carry light from the detector to the PMT's.

Finally, we will develop the connector-to-PMT mapping for the clear fiber cables. Because we have the prototype PMT rack, we have been able to experiment with various arrangements of the the clear fiber routing. We have also been able to spec the length of the clear fiber cables based on our experience with a scale model. While the cable lengths and routing scheme have not yet been finalized, details of the current scheme are available in [4].

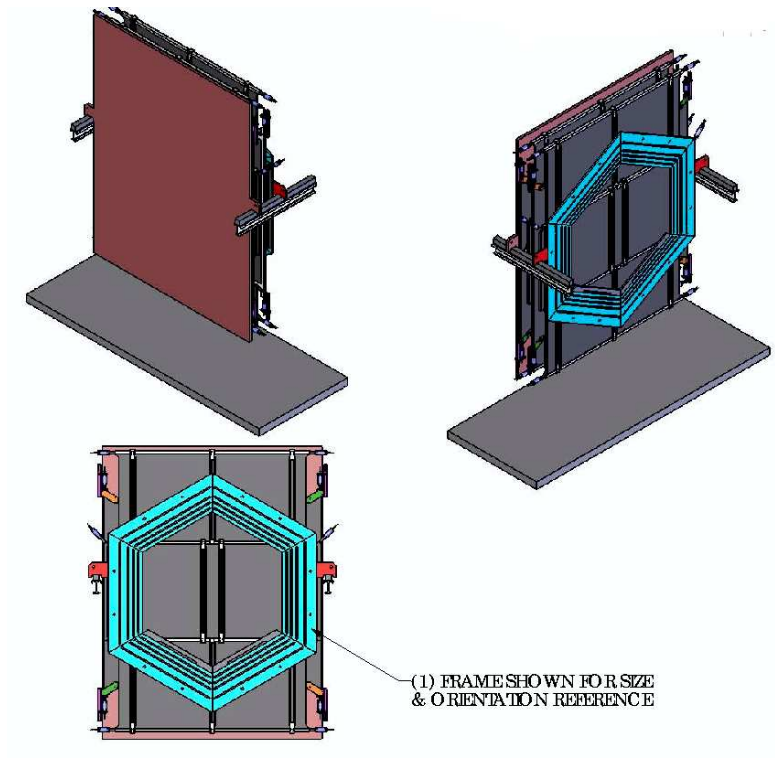

Figure 4.17: Initial engineer's drawing of the veto wall assembly. The veto wall consists of a a large steel plate (shown in purple) followed by two tiled arrays of scintillator counters (in gray). The steel wall and scintillator arrays cover the front end of the detector. Image source: [5].

Construct Veto Wall

The veto wall will be constructed largely from recycled components. The large steel sheet on the US end of the veto wall will be scrap steel from Fermilab surplus. Just downstream of the steel plate will be two walls of scintillator. These walls will be tiled arrays of scintillation counters. The veto wall counters will be constructed with refurbished scintillator taken from the NuTeV experiment. Each panel will have its own WLS light guides and readout PMT's. An initial engineer's drawing of the veto wall in shown in Figure 4.17.

The scintillator panels will be refurbished as part of a summer research program for high school teachers at the University of Rochester. The teachers will re-wrap and test the NuTeV scintillator during the summers of 2006 and 2007. WBS9 will coordinate with and provide some support to the summer research program, and take delivery of the refurbished panels. If any of the scintillator or light guides is found to be unusable, then WBS9 will be responsible for procuring additional panels or light guides.

WBS9 will design the support structure for the steel wall and scintillator arrays. We will have these parts fabricated and transport all veto wall materials to Fermilab.

4.3.2 Facilities and Resources

WBS9 requires facilities from both the University of Rochester and Fermilab.

The R&D effort of WBS9 is centered at the University of Rochester, where we have the core personnel and facilities required to efficiently complete the research effort. This R&D program covers such tasks as development of the initial assembly protocols, testing of materials and tools for use in the module assembly process, refurbishment of the veto wall scintillator, and all design, fabrication, and purchasing tasks. Much of these early tasks are being led by Robert Bradford (the L2 manager for WBS9), Robert Flight (mechanical engineer employed by the UofR Physics Department), Kevin McFarland (MINERνA spokesman), and Dan Ruggiero (UofR technician) with significant contributions provided by both graduate and undergraduate students. Our research group has been provided with laboratory space dedicated to MINERνA .

While the R&D tasks will be well performed in Rochester, the heavier assembly tasks will require the use of Wideband Hall at Fermilab. Wideband Hall provides ample floor space required to safely assemble and map the detector modules, good overhead crane coverage, and a door large enough to permit the passage of modules out of the building for installation. Wideband Hall will be the location for:

1. Construction of the module mapper.
2. Receipt and storage of detector components provided by university groups.
3. The module assembly and mapping factory. All full-sized prototype modules (including the full module prototype and tracking prototype) and final detector modules will be assembled in Wideband Hall.
4. Installation and commissioning and testing of the tracking prototype.
5. Welding of the OD steel frames (done by WBS8).

Within the Hall, we will required several assembly stations, storage space for detector components, storage racks for completed modules and a mapping station. Because the module mapper will contain radioactive sources, the mapping station must be a fenced enclosure posted with appropriate signage. Figure 4.10 shows the proposed layout of Wideband Hall. This layout has been negotiated with WBS8 and reviewed by appropriate safety interests from Fermilab.

Most labor for these heavier tasks will be provided by the University of Rochester. The University employs several experienced technicians who will construct the module mapper, coordinate delivery and receipt of detector components, and assemble and map the modules. The technicians will be supervised by Robert Bradford and other UofR personnel. Bradford will relocate temporarily to Fermilab during times of major activity.

Finally, software for the module mapper will be developed by graduate students from two institutions located in Lima, Peru, the Pontificia Universidad Catolica del Peru and Universidad Nacional de Ingenieria.

4.3.3 Interfaces with other WBS Tasks

WBS9 interfaces most closely with WBS3, 8, and 11. WBS3 provides all scintillator assemblies, both the ID planes and the OD towers. These modules will be constructed at two institutions in Virginia, and then shipped to Fermilab. WBS9 will take delivery of the scintillator units and store them in Wideband Hall. WBS8 will provide steel OD frames for module assembly. The frames will be built in Wideband Hall at the same time that the detector modules are being assembled. Each OD frame will be constructed on one of the three strongbacks in the Wideband Hall assembly area. Having three strongbacks (see Figure 4.10.) will allow frame welding, module assembly, and module mapping to occur in tandem. Frames will be delivered by WBS8 one-at-a-time as they are constructed. After a frame has been constructed, it will remain on the strongback and WBS9 will immediately begin using that frame to construct a detector module. After each production module has been assembled and mapped, it will be moved to a detector stand in Wideband Hall. These modules will be stored here until the detector is installed in the NuMI experimental hall by WBS11. We will also provide WBS11 with the cable routing layouts for the clear fiber cables and PMT racks.

WBS9 has more minor interfaces with several of the other task groups. These interfaces include:

1. WBS4 - Clear Fiber Cables: WBS9 used early prototype models to spec the clear fiber cable lengths for WBS4 and develop the connector-to-PMT mapping scheme. WBS4, in turn, will provide WBS9 will clear fiber cables required for the module mapper and the tracking prototype.
2. WBS5 - PMT boxes: WBS5 will provide WBS9 with six Hammamatsu M-64 PMT's for use with the module mapper and an additional 110 PMT's for the tracking prototype. These PMT's will have been acquired and tested by WBS6; electronic components of the PMT boxes will be supplied by WBS7.
3. WBS7 - Electronics: A prototype data acquisition system will be supplied by WBS7 for use with the module mapper. This will be used to read out the scintillator response as the scintillator planes are scanned by the mapper.

4.3.4 Major Tasks

This section will give an overview of the tasks that we have scheduled for the next several years. The subsections will each refer to a specific task or group of tasks in the MINERνA Project file.

- WBS 9.1.1 - Rochester Prototypes: During the summer of 2005, we constructed wooden models of various detector components. In particular, we built two half-scale detector modules and a full-scale PMT rack. The wooden modules were then used in a series of mock module assembly exercises during which we outlined the assembly protocol, tested materials, and conducted basic time-motion studies. The model PMT rack was used to design the routing scheme of the clear fiber cables.
- WBS 9.1.2 - Full Module Prototype Assembly Fixtures: After studies with the wooden prototypes, then we will prepare for construction of the full-scale module prototype to be built at Fermilab in the Fall of 2006. These preparations include design and fabrication of hardware to be used for the prototype assembly, selection of tools, and acquisition of materials and hardware.
- WBS 9.1.3 - Veto Wall Counters and Veto Wall Design: In the spring and summer of 2006, work will begin on the veto wall. An inventory of the scintillator counters at the University of Rochester will be taken to verify of sizes and quantities of the available counters. Work will then commence on refurbishment and testing of the counters; this will be done by high school teachers

and their students as part of a summer outreach activity lead by Kevin McFarland. The counters will be tested during two summers, 2006 and 2007. At this time, initial engineering drawings will be made on the veto wall to verify that the available counters will be sufficient for the detector's needs.

- WBS 9.1.4 - Design and Construct Mapper: The module mapper will be designed and constructed during the summer and fall of 2006. The design work will be done by a mechanical engineer at the University of Rochester. The same engineer will spec the required parts and begin the procurement. The mapper will require a large number of custom parts. We will have these fabricated by local machine shops so that the engineer will be able to readily interact with the machinists.

  The mapper will be constructed at Fermilab using space in Wideband Hall. Once the parts have been acquired at Rochester, then they will be delivered to Fermilab by truck. The University of Rochester employs several technicians that are resident at Fermilab. One of them will work full-time on the assembly of the mapper.

  At this time, work will also begin on the readout and motion control software for the mapper.

- WBS 9.1.5 - Full Module Prototype Assembly: At the end of 2006, the collaboration will construct one prototype detector module. The module will be full-sized and should be fully functional, but it will be constructed from prototype components. WBS9 will assemble this module. This will provide us with the opportunity to train the technicians using actual components and facilities, further refine our assembly procedures, and test the module mapper.

- WBS 9.1.6 - Module Assembly and Mapping Preparations: 2007 will be spent preparing for assembly of the tracking prototype. This will begin with a redesign of any hardware and facilities based on our experience with the full module prototype. Much of the procurement work for the tracking prototype and final detector will be done this year. We will build the PMT racks, further optimize the module mapper, and fabricate a lifting jig that will be used for PMT installation and maintenance.

- WBS 9.2.1 - Assemble, Map, and Install Tracking Prototype Modules: WBS9 will assemble and map all 20 modules for the tracking prototype, and install all modules into a detector stand in Wideband Hall.

- WBS 9.2.2 - Install Modules at Wideband: Once the modules have been assembled, WBS9 will complete the assembly and installation of the tracking prototype in Wideband Hall. These activities will include installation of PMT racks, PMT's, and all cables. Electronics will be installed by WBS7.

- WBS 9.2.3 - Test and Evaluate Tracking Prototype: We will then commission the tracking prototype. We will have it surveyed to verify that the detector dimensions are within spec and collect cosmic ray data to test tracking. WBS9 will set up a shift schedule and ensure that the counting room is staffed. We will also ensure that all shift takers have been adequately trained.

- WBS 9.3.1 - Veto Wall Assembly: After the tracking prototype has been assembled, then we will complete work on the veto wall. By late 2007, all veto wall counters will have been tested. Based on this information, we will then select the best counters to use in the veto wall. At this point, the design of the veto wall will then be revisited to verify that the support structure will accommodate the actual dimensions of the selected counters. Fabrication of the support structure will be completed and all materials will be shipped to Fermilab. The steel wall will be constructed at Fermilab. All items will be stored until the detector is installed in the NuMI hall.

- WBS 9.3.3 - Assemble and Map Production Modules: In early 2009, we will begin to assemble and map the modules for the MINERνA detector.

4.3.5 Future Work and Engineering

As we are still in the R&D phase of the MINERνA schedule, much of our engineering and optimization work is underway.

While we have practiced and rehearsed our initial assembly procedures, we are attempting to verify that these procedure will be compatible with the actual detector components. The assembly protocols were developed and rehearsed with our half-scale wooden prototype modules. These procedures have been written up in a document which is available in the MINERνA Docdb [4]. We are currently trying to verify our understanding of the OD frames with WBS8 and the scintillator modules with WBS3. These components are crucial for module assembly, so even small changes in the frames or scintillator assemblies could greatly impact WBS9. We are working to finalize a set of engineering drawings of the OD frame with WBS8. Since our initial prototyping efforts, more details of the scintillator assemblies have become available. We have acquired samples of the materials to be used by WBS3, and we are currently testing to verify that our assembly procedures will work well with the scintillator assemblies. These efforts include such tests as verifying that our adhesives will adhere well to the materials that WBS3 has selected. We are also awaiting delivery of a prototype scintillator plane from WBS3 which we will use to verify dimensional tolerances and use to further test compatibility of our procedures. The full module prototype will give us our first chance to test our assembly procedures on actual full-size and full-weight detector components. We anticipate that this exercise will reveal weaknesses in our procedures or materials, so we have scheduled adequate time after the prototype module assembly to revise our assembly procedures and design.

We are also attempting to optimize work flow in light of the module mapper. Currently, the module assembly schedule in the MINERνA Project file is based on a assembly and mapping rate of one module per day. This rate is largely dominated by time required to map a module, which is predicted to be around 20 hours if we scale from the MINOS mapping rate. Based on initial mapper designs, we feel that we may be able to significantly increase the mapping rate by using two scanning heads in the MINERνA module mapper (MINOS mappers each had one scanning head.). The final mapping rate is yet to be determined, but we feel it may be 10-12 hours. Mapping at this rate would lead to a savings in the assembly costs and would remove much of the schedule contingency associated with the module assembly and mapping. This 10-12 hours spec will be the design goal of the mapper. Much remains to be done before we will know if this rate is feasible. Final design of the mapper will take place during the summer of 2006 and the mapper will be first tested on the full module prototype early winter of 2006-2007. Based on the outcomes of this test, we have scheduled time to debug and optimize the mapper in early 2007.

4.4 Detector Installation

WBS11 is responsible for the installation of the detector, as well as a series of physical improvements required to make the NuMI near hall suitable for MINERνA . This work is most closely related to WBS8, and much the work required for WBS11 will be completed by the same individuals.

WBS 11 is not an official part of the Minerva project. There are two major reasons for this. First, all of the infrastructure improvements in this WBS element are tasks that need to be done for the installation of any experiment and are not unique to Minerva. These include the additional drip ceiling, moving the MINOS magnet power supply to make additional room, and installing the quiet power to service any experiment.

Second, the installation of the experiment is off project because with MINOS running the Minerva project has no control over the timing of the installation of the detector. The Minerva project has made various tests with the help of the MINOS experiment to determine how various installation tasks might affect data taking in MINOS. We have taken some test data with the MINOS detector while doing welding and also while using the overhead crane, either of which could generate electronic noise that would interfere with MINOS data taking. While tests so far show minimal effects on MINOS data, the testing has not been comprehensive. Therefore it is entirely possible that Minerva may have to wait for a shutdown to carry out the installation of the detector. In order to define a clear set of CD4 deliverables, then, the detector installation has not officially been included in the MINERνA project.

This section, then, will give an overview of WBS11. Emphasis will be placed on the scope of WBS11, which will be covered in Section 4.4.1. This will be followed by a discussion of required resources (Section 4.4.3 and interfaces with other WBS tasks (Section 4.4.4). An overview of the WBS structure and schedule will not be included.

4.4.1 Task Objectives and Overview

WBS11 has two main objectives. These include, first, preparation of the NuMI near hall to house MINERνA , and second, the actual installation of the detector. These two objectives will be discussed in more detail in the following two subsection.

Improvements to the Numi Near Hall

The WBS11 element provides for installing a drip ceiling over the detector. As the hall is located underground, leakage of groundwater (from above) is a major concern. With MINOS, this situation was remedied by the installation of a drip ceiling above the detector. The drip ceiling is attached to the ceiling of the experimental hall and channels ground water away from the detector. The current drip ceiling is sufficient for MINOS, but would not adequately cover the proposed location of MINERνA .

While it would suffice to simply extend the current drip ceiling to cover the MINERνA detector, we will also solicit quotes for extending the drip ceiling to cover the remainder of Numi near hall. The initial design has been for a simple extension of the same roof system that exists over the MINOS detector, but other kinds of roof systems are also being explored.

Quiet power services in the hall will be expanded with the addition of one more 75 KVA transformer and distribution panel. This addition would allow servicing of one experiments power system without having to shut down both experiments. In the recent shutdown the MINOS power supply and its water skid were moved upstream to the end of the hall. This move will provide extra room for experiments directly upstream of the MINOS detector where space is most valuable. With Minerva in place the power supply would not have been serviceable in the old location if, for example, a transformer needed replacing.

Prior to installation, WBS 11 must install the required detector stands into the NuMI Hall. The detector stand consists of a large rail system that supports the Minerva detector. The detector modules will hang on the rails like a hanging file folder system. Figure 4.9 shows the side view of the detector on the stand. During the installation of the stand the Alignment Group will provide services to make sure the rails are at the proper elevation and that the rails are on the beamline axis. They will also measure the bookend to make sure that all of the frames are hanging plumb on the stand. The stand columns also supply the support for an additional set of rails that hold the phototube access platform over the top of the detector. This access platform allows servicing of the phototube and front end electronics of the detector. The access platform is not shown in Figure 4.9.

4.4.2 Detector Installation

The design of Minerva is similar to MINOS because it is a series of frames that are assembled in a certain order to make up the detector. This allows us to use similar installation techniques that have already been worked out for the assembly of the MINOS detector. Pictures taken during the MINOS detector assembly can illustrate the procedure. Frames are brought over from the Wideband Lab to the MINOS Service building by tractor trailer truck one at a time in the order in which they are installed (from downstream to upstream). The strongbacks will be used as the transport fixture for this. They will maintain the frames flat during transport and will also be the lifting fixture during the lowering and raising crane operations. Figure 4.18 shows a MINOS detector module being lowered into the NuMI Near Hall.

The MINOS surface building has two overhead cranes. The first will be used to load the detector modules off of the flatbed truck and stage them in the surface building. The second crane will then lift the modules and lower them down the access shaft into the experimental hall.

As modules are lowered into the NuMI hall, they will be secured to a cart. The MINOS cart, shown in Figures 4.18 and 4.19, will be re-used for the Minerva installation after some minor modifications. The strongback and frame will be landed on the cart and secured by bolts. Then an electric forklift will be used to push the cart roughly 100 m to the experimental hall.

After the frame is re-secured to the cavern crane it can be unbolted from the cart, moved into position on the detector stand and set in place. The frame will be secured to the detector by axial bolts that keep a uniform distance between frames. A bookend on the downstream end of the stand provides a framework that ensures that the assembly of the detector starts from a straight reference plane. During assembly of the following frames frequent measurements will be taken and adjustments made to maintain the detector straight and plumb. Figure 4.20 illustrates the mounting of a MINOS detector module.

As each module is installed, some quality assurance and testing will be done. Modules will be visually inspected for damage during transport and handling. The light-tightness of each module will also be verified.

As every four modules are installed, a PMT rack will be installed on top. This rack will hold all of the PMT's required to read out the four modules. The PMT's and electronics will be installed, and each module will be tested further.

After the detector is assembled a phototube access platform will be installed on its own rails. This platform will allow for routine maintenance of the phototubes without the need of special equipment.

Figure 4.18: MINOS detector module being lowered into the cavern at the shaft.

Figure 4.19: Cart in the Numi Near Hall holding a MINOS detector module.

Figure 4.20: Mounting a MINOS module on the detector stand.

4.4.3 Facilities and Resources

Most of heavy work associated with detector installation will be handled by Fermilab technicians. WBS11 will employ the crew used by WBS8 for the OD frame assembly and welding; this is also the same crew who handled the installation of the MINOS near detector. This crew will install the detector stand, handle installation of the detector modules, and install the PMT access platform.

At the time of installation, some physicist involvement will be required. In particular, a group from the University of Rochester will help install the PMT's and clear fiber cables, and test the modules. This group is associated with WBS9. Having been heavily involved in module assembly, they will be familiar with module QA procedures. WBS9 is responsible for commissioning the tracking prototype, so Rochester technicians and physicists will help test and commission each module as they are installed. Representatives from other task groups will handle installation and testing of the electronics and data acquisition system.

As discussed in the previous section, WBS11 will make use of Wideband Hall, the MINOS surface building and the NuMI hall. Before installation, the assembled modules will be stored in Wideband Hall. All three locations are equipped with adequate overhead cranes to handle any lifting operations required. A flatbed truck will be required to transport modules from Wideband Hall to the MINOS surface building, and an electronic fork lift will be used in the NuMI experimental hall to push the cart which moves modules from the bottom of the access shaft to the staging area for the overhead crane.

4.4.4 Interfaces with other WBS Tasks

WBS 11 will interface most closely with WBS9. WBS9 will deliver the assembled modules to WBS11. These modules will be hanging on a storage rack in Wideband Hall. In addition, WBS9 will provide the PMT racks and the veto wall.

PMTs in boxes will be provided by WBS6, and electronics will be provided by WBS7.

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